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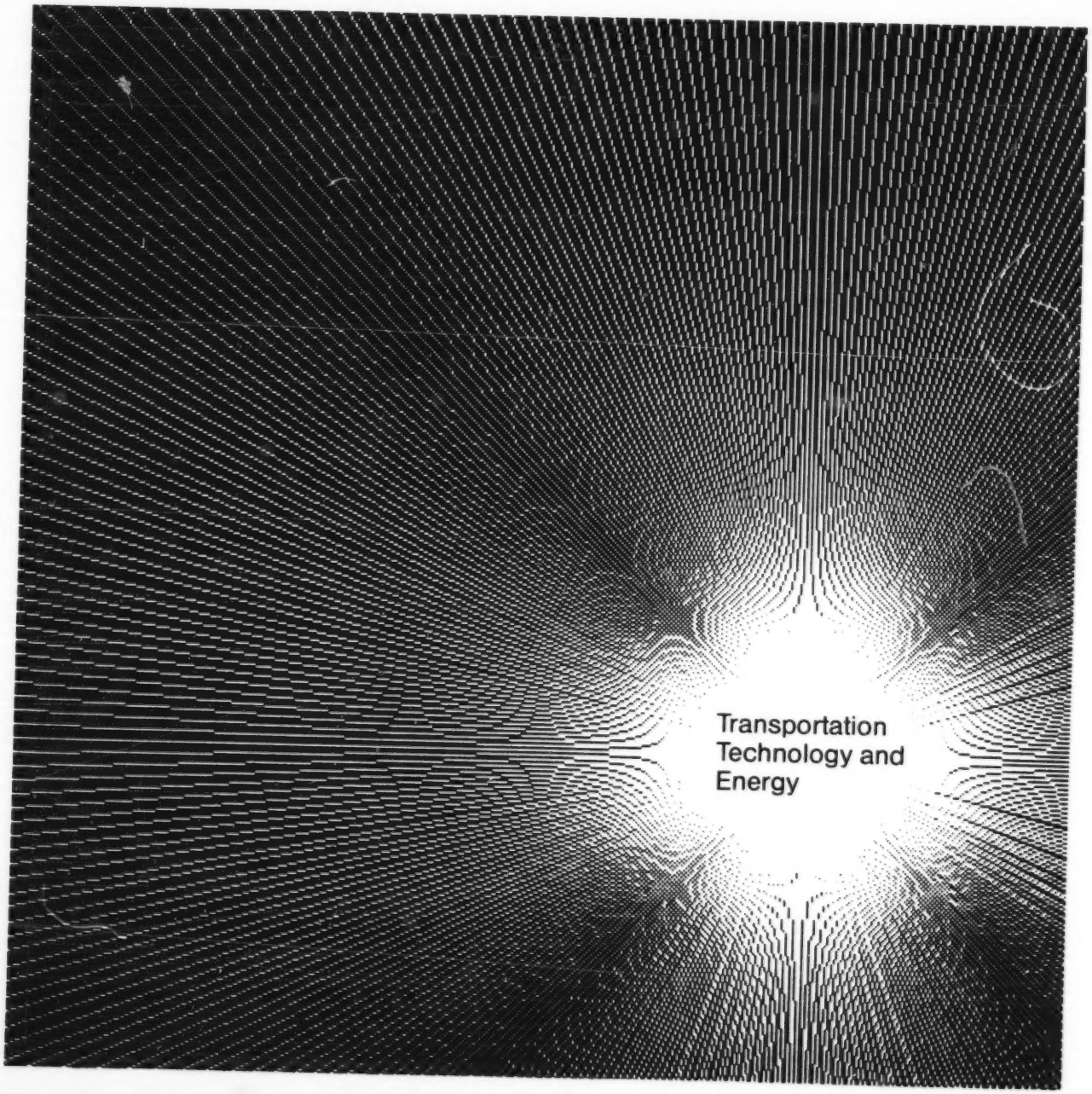

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J. Tsai
Project Research Engineer
Transit Control Technology and Systems Office

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WIDE AREA VEHICLE MONITORING (WAVM) SYSTEM PROJECT FOR ONTARIO'S TRUCKING INDUSTRY

Tsai, J.

ABSTRACT

For quite some time, automatic vehicle monitoring (AVM) systems have been applied to improve scheduling and operational efficiency of fixed-route vehicle fleets operating in a small area such as within city boundaries. One example is the Toronto Transit Commission's bus communication and information system. However, lack of proper land navigation and mobile communications technologies to cover a wide area has hampered the application of the AVM system to improve intercity truck fleet operating efficiency and safety.

Recent development of the NAVSTAR Global Position System (GPS) in the US, the Mobile Satellite (MSAT) in Canada and the US, and cellular radio technology has created an opportunity to develop a Wide Area Vehicle Monitoring (WAVM) system for use by intercity truck fleets. The GPS is a continuous, all-weather, worldwide satellite navigation system. Eighteen GPS satellites will provide a continuous stream of coded signals for the vehicle to derive its three-dimensional position and velocity. For land transportation applications, two-dimensional coverage will be available in the late 1980's. Since MSAT and/or cellular radio will cover North America, it will provide the two-way communication channels required between a truck and its base station from coast to coast. Cellular communication service is currently available, and the MSAT service will be available in 1992.

The WAVM system is an application of these satellite navigation and communications technologies. It is conceptually a computerized vehicle monitoring and management system capable of operating from coast to coast and providing two-way communications between a truck and its base station. The WAVM system will allow new wide area irregular route service, just-in-time service, and dangerous or valuable cargo tracking service to be efficiently provided by the trucking industry. Knowing exactly the overall operating status of the truck fleet at any given point in time, the truck fleet manager can select or devise the optimum operating plan or schedule to maximize operating efficiency, profit, and safety. Application of WAVM system technology will represent a major change and improvement in truck dispatching and management philosophies.

Recognizing the potential of WAVM system technology, the Ontario Ministry of Transportation and Communications (MTC) has initiated a WAVM system project to promote the system's applications by the Ontario trucking industry. Due to the enthusiastic responses from the industry, a joint demonstration

project group consisting of trucking companies, high technology service and equipment suppliers, and MTC is planned and organized. The purpose of the WAVM project group is to demonstrate the WAVM system applications in the truck fleet sector and to promote this high technology product opportunity to the industry. This paper describes the WAVM project background, current status and efforts, and the preliminary results.

INTRODUCTION

The Wide Area Vehicle Monitoring (WAVM) system is an application of satellite navigation and communications technologies. Figure 1 shows the WAVM system concept configuration. The WAVM system will be capable of operating from coast to coast in North America. It will provide vehicle position data and two-way communications services between the equipped trucks and the trucking company's base station.

As shown in Figure 2, the WAVM system will be an important link, which is missing currently, between the trucking companies and their fleets. The system will be a powerful new tool for the trucking companies to optimize asset utilization and improve vehicle productivity. Recognizing the potential of WAVM system technology, MTC has organized a WAVM project group including trucking companies and high technology service and equipment suppliers to focus the effort of the users, suppliers, and government agencies in expediting the realization of WAVM system application by the trucking industry.

The WAVM project group is organized
- to promote user awareness and identify user requirements,
- to demonstrate WAVM system applications and benefits in truck fleet management and control, and
- to pursue the high technology product market opportunity with the supplier industry.

CURRENT TRUCK FLEET OPERATING METHOD AND PROBLEMS

To appreciate the potential impact of the WAVM system on the trucking industry, one has to look at where the trucking companies operate and how they operate.

TRUCK FLEET OPERATING METHOD

Figure 3 shows a typical truck route diagram [1] for a long-haul trucking operation. From the physical distribution point of view, the long-haul trucking operation is characterized by interprovincial, interstate, and international truck routes. The truck routes may be fixed routes from point to point or irregular routes (random routes) from coast to coast, depending on the customers' demands. Figure 4 shows a typical Southern Ontario truck route diagram [1] for regional trucking operation. Regional trucking operations typically consist of intercity or international truck routes and very often involve a just-in-time trucking operation. In both cases, the truck fleet operation covers a very wide geographical area.

The management of the truck fleet is also characterized by conventional technology applications. Figure 5 shows a typical truck fleet dispatch method. In a manual dispatch system, the

driver picks up goods distribution orders from the dispatcher and drives the truck out to serve the customers. The truck drivers will typically contact the head office once or twice a day by telephone if they can find one. A more sophisticated dispatch operation involves the use of a computerized dispatch system. The computerized dispatch system stores the customer, truck fleet, and driver data bases. Based on the customers' current demands and stored data base information, the computerized dispatch system will assist the dispatcher to match the shipping demands with the available trucks and drivers. However, once a truck is dispatched, the head office almost immediately loses the contact with the truck until the driver calls back many hours later.

TRUCK FLEET OPERATING PROBLEMS

Two problems facing trucking companies are that they are unable to contact their drivers at will and are unaware of the exact location of their trucks at any given time.

If a trucking company has one or two tractor-trailers and operates in a small area, these types of operational problems may not be very serious. However, if a trucking company has hundreds or thousands of tractor-trailers and operates in a wide geographic area, the need to keep track of the trucks and co-ordinate overall fleet operation in real time becomes very urgent. Furthermore, the introduction of the just-in-time transportation service by the industry also places a critical demand on the timing of goods delivery from the origin to the destination. Effective co-ordination for the just-in-time transportation service and other wide area trucking operations so that each truck and every driver are efficiently used to serve each customer's shipping demands will require the knowledge of the truck location and the ability to reach the driver at will in real time.

WAVM SYSTEM TECHNOLOGY

For quite some time, automatic vehicle monitoring (AVM) [2] systems have been applied to improve scheduling and operational efficiency for fixed-route vehicle fleets operating in a small area such as within city boundaries. One example is the Toronto Transit Commission's bus communications and information system. However, lack of proper land navigation and mobile communications technologies to cover a wide area has hampered the application of the AVM system to improve truck fleet operating efficiency and safety.

Recent development of the NAVSTAR Global Position System (GPS) [3,4] in the US, the Mobile Satellite (MSAT) [5,6,7] in Canada and the US, the enhancement of LORAN-C land-based navigation capability, and cellular radio technology has created an

opportunity to develop a Wide Area Vehicle Monitoring (WAVM) system for use by truck fleets.

GLOBAL POSITIONING SYSTEM

The NAVSTAR GPS (Figure 6) is a continuous, all-weather, world-wide satellite navigation system. Eighteen GPS satellites will provide a continuous stream of coded signals for the vehicle to derive its three-dimensional position (latitude, longitude, and elevation) and velocity. The real-time positional accuracy for civil applications is better than 100 m. The velocity measurement has an accuracy of 0.1 m/s. For land transportation applications, two-dimensional coverage will be available in the late 1980s. Currently, there are six GPS satellites in orbit for equipment development testing and limited positioning services.

US auto makers in Detroit have already demonstrated the GPS navigation system for the family car and plan to offer their vehicle locator system as an option in the near future. This system comprises only one-half of the WAVM system concept because the vehicle position and velocity information is not communicated back to a central base station.

MOBILE SATELLITE AND CELLULAR RADIO SERVICES

Since MSAT and/or cellular radio will cover North America, it will provide the two-way communication channels required between a vehicle and its base station from coast to coast. Figure 7 shows the MSAT system concept. MSAT service will be a co-operative effort between the US and Canada. Figure 8 shows the proposed antenna coverage for the North American continent. It is expected that the service will be compatible in the US and Canada. This is a very important feature, since many Ontario trucking companies operate in both countries and there are many cross-the-border trucking operations. The MSAT service is expected to become available in 1992.

Cellular communications service is currently available in the major urban centres and corridors of both the US and Canada. Figure 9 shows the cellular radio concept. The important feature of the cellular radio service is that the service area is divided into many small cells. The allocated radio channels in one cell can be reused in the other cells within the same service area. As a result, there is virtually an unlimited number of radio channels for the mobile communications applications. In fact, this technique will also be used in the mobile satellite service. Another important feature of the cellular communications is the roaming service. Roaming service will allow a user to call a cellular mobile unit operating out of its own home region. Figure 10 shows that the cellular service covers the Oshawa-to-Windsor corridor in Southern Ontario. The roaming service will allow the user to call a cellular mobile unit operating in the other urban centres and corridor areas.

Therefore, a limited wide area coverage is provided by the cellular communications service at the present time. The coverage area of the cellular service is also expanded almost on a daily basis.

WAVM SYSTEM CONCEPT AND ITS APPLICATIONS

WAVM CONCEPT

Based on the preceding positioning and communications technologies, a WAVM system concept was conceived for trucking industry applications. Figure 11 shows the functional diagram of the WAVM system. Essentially, the WAVM system uses a microprocessor-based vehicle subsystem (on-board unit) to provide truck position locating capability and truck-to-base station two-way communications capability. The vehicle subsystem will consist of a WAVM mobile data terminal (for control and display) connected with GPS user equipment and a mobile satellite communications terminal. Based on the GPS satellite signals, the GPS equipment will continuously compute and update the truck's position and velocity data, which will be transmitted by the mobile satellite communications terminal. At the WAVM base station, a microcomputer system with a communications device and a graphic/alphanumeric display unit would communicate with the trucks in the field through MSAT channels or cellular radio channels to receive truck identification, position, and velocity information and to transmit messages to direct the trucks in the field. The truck fleet manager at the base station would have the real-time information on the identity of the trucks, the location of the trucks, where the trucks are going, and what they are doing, e.g., speeding or idling.

This real-time truck fleet information can be updated automatically and displayed on the graphic/alphanumeric display unit as frequently as desired by the trucking companies. The advantages of the proposed WAVM system over the MSAT-only-based system is that WAVM can automatically report a truck's location and velocity information without the driver's intervention. Thus, a driver can concentrate on his driving task. Another advantage is that the WAVM system relies mainly on the data communications method to automatically gather truck status information and to convey the messages to the truck driver from the truck fleet base station. The messages could be conveyed to the driver through an electronic display device and/or a beeping sound device. Voice communication would only be used as a supplementary method. Data transmission is more efficient than the voice transmission in utilizing the communication channel. As a result, WAVM would be a more cost-effective system than the voice-communication-based systems.

WAVM APPLICATIONS

The proposed WAVM system would allow trucking companies to improve their operational efficiency and safety in general goods distribution and to keep track of valuable or dangerous cargoes. Knowing exactly the overall operating status of the truck fleet at any given point in time, the truck fleet manager could select or devise the optimum operating plan or schedule to maximize operation efficiency, safety, and profit. The WAVM system is expected to become an effective tool for the truck fleet operating agencies in improving their daily operation control.

In addition, other vehicle on-board information and control subsystems, such as speed control, weight control, trip recorders, transmission control, and diagnostics, etc., could be integrated with the WAVM system, and all of this information could be transmitted back to truck fleet base station for management action.

By allowing a central dispatcher/microcomputer to automatically gather and display information on each truck's identification, location, and velocity in real time for the transportation manager, decisions concerning the fleet's dispersion, operational status, route planning, and scheduling adjustment can be made in real time. The decision made by the transportation manager could then be transmitted in real time to the truck by the WAVM system and conveyed to the driver through an electronic message display unit, beep sound, or synthesized voice device. A truck driver could communicate with the base station through a simple and small keyboard input device or function buttons. Voice communications could also be provided as a supplementary device.

This type of real-time vehicle fleet command and control system represents a major change and improvement to truck dispatching and management philosophies and will allow new methods of trucking operation to be used by the industry.

COMPETING TECHNOLOGY AND WAVM INDUSTRY PRODUCT OPPORTUNITY

In addition to the potential applications in the trucking industry, WAVM systems may also be used by other land-based transportation sectors. The Canadian trucking industry is an $11 billion business, and the US trucking industry is a $200 billion business. In short, trucking is a big transportation business. More specifically, there are more than nine million commercial vehicles [8] in the US and over half a million commercial vehicles [9] in Canada. Table 1 shows the potential land-based user market size in the US.

In Canada, for-hire carriers operate a fleet of some 129 000 vehicles and the private trucking industry is estimated to operate 376 600 vehicles [9]. From the preceding data, the potential WAVM market size in North America is large.

This market potential has not been overlooked by the mobile communications service industry. Several competitive services have been planned and implemented. Table 2 shows the capability of different services provided or to be provided [10].

MSAT, once implemented, will provide the best communications capability and coverage area for WAVM applications. However, it is not planned to be available until 1992. Other services such as TRACS, INMARSAT, GEOSTAR, and CELLULAR RADIO don't have adequate coverage area and communications capability at the present time; some of these services are available in 1986, but others will not be available until 1987. Also, their communications capability and coverage area may be expanded with increasing customer's demands in the future.

In the vehicle positioning system area, there are also many competitive position-locating services available. Table 3 shows the capability of different services available [11].

From Table 3, it is clear that GPS has the best capability in terms of position accuracy and coverage area for WAVM applications. LORAN-C may also be used as a position-locating device, although it only covers part of North America. The "ultimate" WAVM system will have MSAT as well as cellular communications capability, in addition to GPS positioning capability.

Depending on applications, accuracy demand, and user requirements, there are many possible WAVM systems and equipment configurations. Table 4 shows areas of opportunity related to WAVM systems applications based on the combination of navigation and communications technologies.

There are obviously many different product opportunities for the high technology industry to explore for the supply of WAVM equipment, systems, and services to the trucking industry.

WAVM PROJECT APPROACH

After identifying the potential of the WAVM system technology, MTC then initiated the WAVM system project in late 1984 to promote its applications by the Ontario trucking industry. The WAVM project consists of four steps:

1/ survey the trucking industry's requirements,
2/ co-ordinate joint demonstration with the trucking and electronic industries,
3/ promote and assist the trucking industry in WAVM system applications, and
4/ encourage high technology product development by the Ontario electronic industry.

It is widely expected by the industry that the component cost of the WAVM system for land transportation applications will reach a level which can be afforded by a large group of users.

A WAVM system demonstration will focus the effort of the users, suppliers, and government agencies to expedite the realization of the WAVM system applications by the trucking industry.

Deregulation of the North American transportation industry will also intensify the operation efficiency competition. By promoting the WAVM system applications, MTC can assist the Ontario trucking industry to respond to this challenge and remain competitive. It can also generate a high technology product market for the supplier industry.

The roles of MTC in this project are to conduct technology evaluation, application, and transfer and to perform project formulation, co-ordination, and management.

ONTARIO TRUCKING INDUSTRY SURVEY FOR WAVM APPLICATIONS

Although the technology, hardware, and software are just emerging, it is certain that the application of WAVM technology will require a system approach tailored to the trucking companies' requirements and needs.

A truck industry survey was carried out between April and August 1985 to construct a profile of the potential WAVM system users. Information was gathered on the expected WAVM applications and system requirements, the perceived benefits and the affordable cost, and users' concerns and preferred implementation strategy.

The information was obtained from for-hire carriers through questionnaires and a series of interviews. The questionnaire was mailed to 97 Ontario for-hire carriers. Thirty-three of the 97 responded. This is a very high response level (34%) and is an indication of the interest shown towards the topic. This survey covered over 20 000 commercial vehicles.

A cross-section of for-hire carriers was selected for the survey. The carriers surveyed represent a wide range of annual revenue categories (Figure 12): 6% have an annual revenue of less than one million dollars; 30% have one to five million dollars; 36% have five to twenty-five million dollars; and 27% have an annual revenue of more than twenty-five million dollars.

Forty-six percent of the carriers surveyed are Ontario-wide, 22% are interprovincial, 16% are international, and the remaining 16% are local trucking businesses (Figure 13).

The survey data were evaluated to assess potential WAVM user profiles, perceived applications and benefits, system requirements, and market potential.

ONTARIO TRUCK FLEET'S DISPATCH AND COMMUNICATIONS

Many trucking companies have begun to use a computer dispatch system (CDS) to manage their truck fleet's operation. In fact, 24% of the surveyed for-hire carriers employ a CDS to assist dispatchers in managing fleet operation. In general, a CDS, in conjunction with telephone and/or mobile radio, is used to assist the dispatcher to schedule the trucks and the drivers to meet customer shipping demands. Voice conversation between the dispatcher and the driver is the main communication method. There is generally no direct data exchange between a CDS and the truck on the road.

Current truck fleet communication methods between fleet dispatchers and truck drivers are as follows: 80% of long-haul, short-haul, and city-wide fleet operations generally use conventional land-line telephones. Thirteen percent of short-haul and city-wide operations use mobile telephones, 45% use a private ratio mobile network, and 6% use mobile data radio dispatch.

Mobile telephone, private radio mobile network, and mobile data radio dispatch can only be used in short-haul and city-wide trucking operations and are only used by up to 45% of the carriers. The majority (80%) of the carriers are still relying on the conventional land-line telephone for overall fleet communications. This means that once a truck leaves the terminal, the dispatcher has no way of contacting the truck again until the driver stops over at a place with a telephone to call the base station. Due to this constraint, a truck driver usually calls the base station only once or twice a day while on the road.

As expected, this type of truck fleet management is effective only when the operation is limited to a small area covered by the conventional mobile radio system. In long- and short-haul operations, the conventional mobile radio system can not provide adequate coverage. This usually means a trucking operation at more than 50 km from a metropolitan area will have to rely on the conventional telephone. As a result, the real-time fleet monitoring function is not provided in the current CDS used by long- or short-haul trucking companies.

The proposed WAVM system has been considered by many trucking companies as a missing link between their CDS and their truck fleet on the road. It is also viewed by trucking companies without CDS as a system which will provide computerized truck fleet monitoring and dispatching services to the fleet managers.

INTEREST IN WAVM SYSTEM APPLICATIONS

Seventy-five percent of all the for-hire carriers who participated in the survey are interested in WAVM system applications. Based on revenue (Figure 14) this figure breaks down to 50% of those carriers in the less than one-million-dollar category, 60% of carriers in the one-to-five-million dollar category, 85% in the five-to-twenty-five-million-dollar category, and 95% in the over twenty-five-million-dollar category. It can be concluded that the higher interest groups are the higher revenue carriers.

Common highway carriers (Figure 15) appear to be more interested in WAVM (80% surveyed expressed interest) than the contract highway carriers (50% expressed interest). Almost all the parcel and courier service providers are interested in WAVM system applications.

EXPECTED WAVM APPLICATIONS AND PERCEIVED BENEFITS

Fore-hire carriers expect a great deal from WAVM technology, both in terms of applications and benefits. Figure 16 shows the expected WAVM system applications by for-hire carriers. The majority of the carriers indicate that they will use the WAVM system regularly for the following applications:

- vehicle location and velocity monitoring (75%)
- just-in-time service (73%)
- provide MIS data (64%)
- schedule and headway adherence (61%)
- schedule and route planning (55%)
- dangerous/valuable cargoes tracking (52%)

Less than half (48%) of the for-hire carriers also express that they will use WAVM regularly for fleet security monitoring.

The majority of the for-hire carriers consider that WAVM will result in better customer services (76%), improved random pickup and delivery operation (73%) and improved scheduling and routing (61%), better management decisions (61%), increased profits (61%) and improved cross-country fleet operation (52%) (Figure 17).

To a lesser degree, the following benefits are also perceived: improved city-wide fleet operation (48%), reduced fuel cost (45%), fleet security (42%), and improved fixed-route operation (24%).

In general, the WAVM system is perceived to be an invaluable tool for irregular-route trucking operations.

THE WAVM SYSTEM REQUIREMENTS

To achieve the desired applications and the perceived system benefits, the WAVM system must operate in a way required by the

potential users and must possess the required system components to perform the necessary functions. Figure 18 shows the period of information exchange required for the vehicle location monitoring function. The majority (64%) of the carriers indicate that for this function to be of practical application, the information exchange between the base station and the truck fleet on the road should take place at less than 2 h intervals.

Figure 19 shows the period of information exchange required for the vehicle schedule and route adjustment function. The majority (64%) of the carriers also indicate that for this application, the information exchange should take place at less than 2 h intervals. In both cases, over 40% of the carriers feel that information exchange should take place at less than 1 h intervals. It can be concluded that a WAVM system designed to take a "snapshot" of the fleet's status at 1 h intervals will probably satisfy 90% of the users' needs.

In addition to fundamental vehicle on-board devices, such as a GPS vehicle locator device to provide vehicle location data and a satellite communication terminal to provide data communication channels, for-hire carriers also indicate the following preferred on-board equipment:
- electronic message display (76%)
- voice communication (64%)
- keyboard device (44%)
- electronic synthesized voice (20%)
- audio alarm/beep (16%)
- electronic map display (16%)

Figure 20 shows the preference of additional vehicle on-board equipment. It is interesting to note that the in-vehicle electronic map display device is not perceived by the for-hire carriers as an absolutely necessary item. On the other hand, for-hire carriers are more eager to accept simple devices such as electronic message displays and input keyboards.

There is also a strong desire on the part of some for-hire carriers to tie the WAVM system into other truck electronic subsystems, such as a fuel reporting system, a trip and vehicle status reporting system, a weight monitoring system, and a driver alertness monitoring system for integrated system operation. Some of the comments indicated that, in this regard, the WAVM system presents exceptional possibilities, and great potential for effective route control. The comments also indicated that knowlege of the vehicles' locations at all times would be invaluable.

AFFORDABLE WAVM SYSTEM COST

For WAVM system applications to become a reality, the system has to be priced in a range affordable by the trucking industry. Figure 21 shows the acceptable/affordable cost of WAVM

vehicle on-board unit. Eighty-eight percent of the carriers indicate that the unit cost should be priced under $3000.00. Another 16% indicate that the unit cost should be less than 5% of a truck cost. This is equivalent to $5000.00 per unit, assuming a truck costs $100,000.00. Based on this survey, it appears that $5000.00 is the upper price limit for the WAVM on-board unit.

Figure 22 shows the affordable cost of a WAVM base station control system. Seventy-six percent of the carriers indicate that the WAVM base station control system should be priced under $20,000.00. Another 16% indicate that the base station system should be less than 3% of the truck fleet cost. This will be equivalent to $300,000.00 per base station system for a 100-truck fleet. There is a wider opinion gap on the cost of a base station system. This may be due to different capability perception for a base station system. The cost of the base station system will be more or less determined by the number of control functions a carrier wants to have.

WAVM IMPLEMENTATION STRATEGY AND INDUSTRY'S CONCERNS

When asked which WAVM system implementation strategy (Figure 23) they would prefer, the majority, 52%, of the carriers expressed a preference for "leasing a system with an option to buy." This is perhaps a prudent approach when dealing with the application of a new technology. Twenty percent indicated that they would prefer straight leasing. Interestingly, 20% of the carriers indicate that they want to develop the system in-house, while 25% would buy the system off-the-shelf.

Truckers' concerns regarding application of the WAVM system include: cost, uncertain return on investment, interference or monitoring by other parties, bugs in the system, driver distraction, morale and education, and security against theft. As expected, the system cost is the concern expressed most often. However, positive comments from the industry outweigh the negative concerns.

MARKET POTENTIAL OF WAVM SYSTEM

Whether suppliers can provide WAVM system at a cost affordable by the trucking industry may depend on the size of the potential WAVM system market. If there is a large market size, then the manufacturing cost can be shared by the large quantity of the units produced. Figure 24 shows the percentage of vehicles to be covered by WAVM system. For the for-hire carriers which have expressed interest (75% of them) in WAVM system applications, 70% of their tractor-trailers, 80% of their straight trucks, and 78% of their vans will be covered by WAVM. Considering that there are over nine million vehicles which can use WAVM technology in North America alone, the potential market size is very large.

SURVEY CONCLUSION

Based on the survey data, one can conclude the following:

1/ The WAVM system will allow new trucking services such as wide area irregular route service, just-in-time trucking service, cargo tracking service, etc., to be more efficiently provided by the industry.

2/ The WAVM system will allow the truck fleet manager to apply an optimum operating plan or schedule to maximize efficiency, safety, and profit.

3) A reasonably priced WAVM system will be welcomed by the Ontario trucking industry.

This survey has confirmed the perceived potential of the WAVM system and has provided a foundation for further co-operative effort among the Ontario trucking industry, supplier industry, and government agencies.

JOINT WAVM DEMONSTRATION PLAN AND PRELIMINARY RESULTS

JOINT WAVM DEMONSTRATION PLAN

Encouraged by the survey results, a WAVM demonstration project plan was proposed to the industry for consideration. The responses from industry on the proposed demonstration plan are extremely enthusiastic. They indicated that they would provide staff to work with MTC in setting up and conducting the experiment; would provide partial funding for the experiment; and look forward to his project with a great deal of enthusiasm as it brings a new era to transportation.

WAVM PROJECT GROUP AND ACCOMPLISHMENT

As a result of the positive responses from the industry on the WAVM technology and the large potential market size, a joint demonstration project group consisting of trucking companies, high technology services and equipment suppliers, and government is planned and organized. The involved trucking companies are engaged in providing wide area irregular route service, fixed- route service, and just-in-time service. The purpose of the WAVM project group is to demonstrate WAVM system applications in the truck fleet sector and to promote the high technology product opportunity to the industry.

In a very short period of six months, the WAVM project group has evaluated different vehicle positioning and communications technologies for possible WAVM demonstration and has also defined the WAVM system operating requirements based on the participating trucking companies' needs and requirements. The

document for the WAVM system operating requirements has been presented to the potential services providers and equipment suppliers for the development and design of an appropriate WAVM system for trucking industry applications.

The WAVM project group has also become a focus point for the effort of the users, suppliers, and government agencies in expediting the realization of WAVM system applications.

FUTURE ACTION

Based on the availability time frame of various navigation and mobile communications service infrastructures, the WAVM project group has adopted an interim WAVM demonstration plan. The interim demonstration plan will cover the time frame from 1987 to 1992. When MSAT is launched in 1992, the interim demonstration system is expected to be transformed into a MSAT-based WAVM system with minimum change in hardware and software components. Figure 25 shows the existing mobile satellite-based WAVM demonstration configuration. In the interim demonstration configurations, either the GPS position receiver or LORAN-C receiver may be used for truck position locating purposes. The planning for the interim existing satellite-based WAVM demonstration is expected to be completed in late 1987, and the actual demonstration will take place in 1988. In the demonstration, the WAVM system will have to be integrated into a trucking company's current fleet dispatching system, customer, and vehicle maintenance information system.

To pursue WAVM-related high technology product market opportunity, the industry is encouraged to take the initiate to develop the WAVM equipment and system, based on the WAVM system operating requirements.

CONCLUSION

Two general conclusions can be drawn from the survey results: The WAVM system will become an important link between the trucking companies and their fleets, and the system will be a powerful new tool for the trucking companies to optimize asset utilization and to improve vehicle productivity.

Through the effort of the WAVM demonstration project group, it is expected that when the MSAT is launched in 1992, the trucking industry will have the WAVM system integrated, operational staff trained, and organization structured to apply the WAVM technology for daily operation. Also, the equipment industry will have the capability to provide WAVM equipment affordable by the users and will be ready for a wider market. The service industry will provide WAVM communications services affordable by the users.

A broader aspect of the WAVM project is that the system has potential worldwide trucking industry applications. It also has potential applications in bus, rail, marine, and air sectors. It may also be utilized in various highway heavy vehicle monitoring projects.

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[10] "Wide Area Vehicle Management Early Entry Satellite-based Service Concepts," Presentation at WAVM Project Group Meeting by Telesat Canada, Ottawa, June 4, 1986.

[11] "NAVSTAR Global Positioning System Receiver," Brochure, Rockwell International, US 1985.

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2/ Mobile Communications Services Comparison Table
3/ Vehicle Positioning Services Comparison Table
4/ Potential WAVM Product Opportunity Matrix

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Table 1/ Potential Land-Based Market

Type of Vehicles	Number of Vehicles
Intercity trucks	3 000 000
Delivery vehicles	3 000 000
Buses	50 000
Railroad cars	1 000 000
Emergency & security (police, fire, medical)	1 000 000
Taxis	1 000 000
TOTAL	9 050 000

Table 2/ Mobile Communications Services Comparison Table

System	Capability	Timing	Coverage
TRACS	1-way data to truck	1987	Southern Canada and US
INMARSAT	2-way data between truck & HQ	1988	East/west coasts (Ontario)
GEOSTAR	1-way data to HQ 2-way data planned	1988	St. Lawrence and US
MSAT	2-way data & voice between truck & HQ	1992	Continental US and Canada
CELLULAR RADIO	2-way data & voice between truck & HQ	1986	Major urban centres and corridor areas

Table 3/ Vehicle Positioning Services Comparison Table

System	Position Accuracy (M)	Velocity Accuracy (M/Sec)	Range of Operation	Operation
GPS	100 (3-D, civil)	0.1	Worldwide	Operational worldwide with 24 h all weather coverage; limited service available now.
LORAN-C	180	--	63% Continental US, Southern Ontario	Operational with localized coverage. Accuracy suffers during bad weather.
Omega	2200	--	90% global coverage	Currently operational with localized coverage. System loses accuracy in bad weather.
Transit (Satellite)	200	--	Worldwide	The interval between position fix is about 90 min.
INS	1500 max after 1st hour	0.8 after 2 h	Worldwide	Operational worldwide with 24 h all weather coverage.

Table 4/ Potential WAVM Product Opportunity Matrix

	GPS/LORAN-C
MSAT/INMARSAT ETC.	Wide area vehicle monitor and dispatch
CELLULAR RADIO	Corridor area vehicle monitor and dispatch
CONVENTIONAL RADIO	Small area vehicle monitor and dispatch

Figure 1/ Wide Area Vehicle Monitoring System Concept

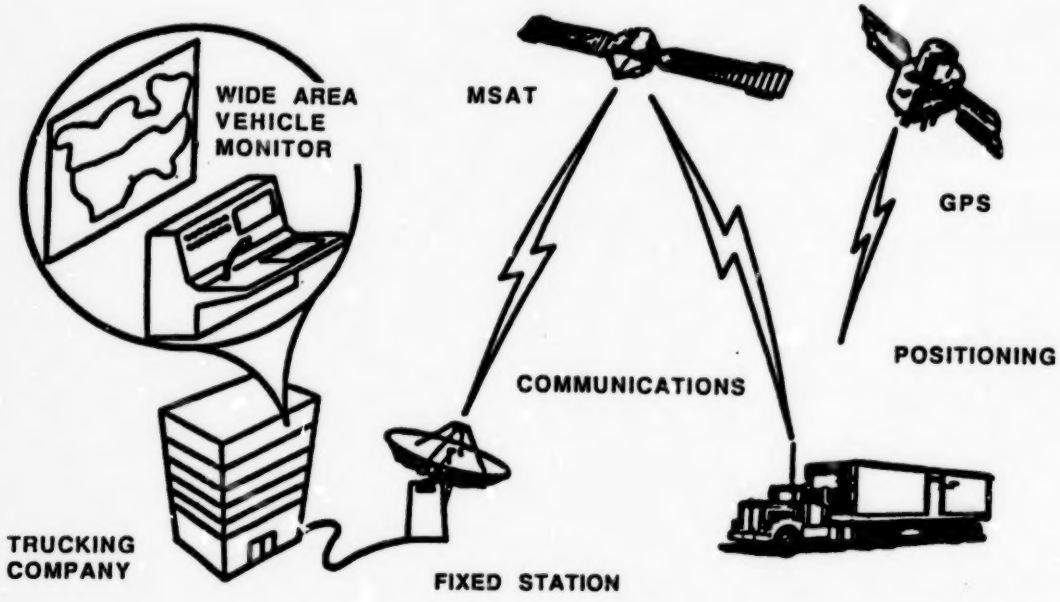
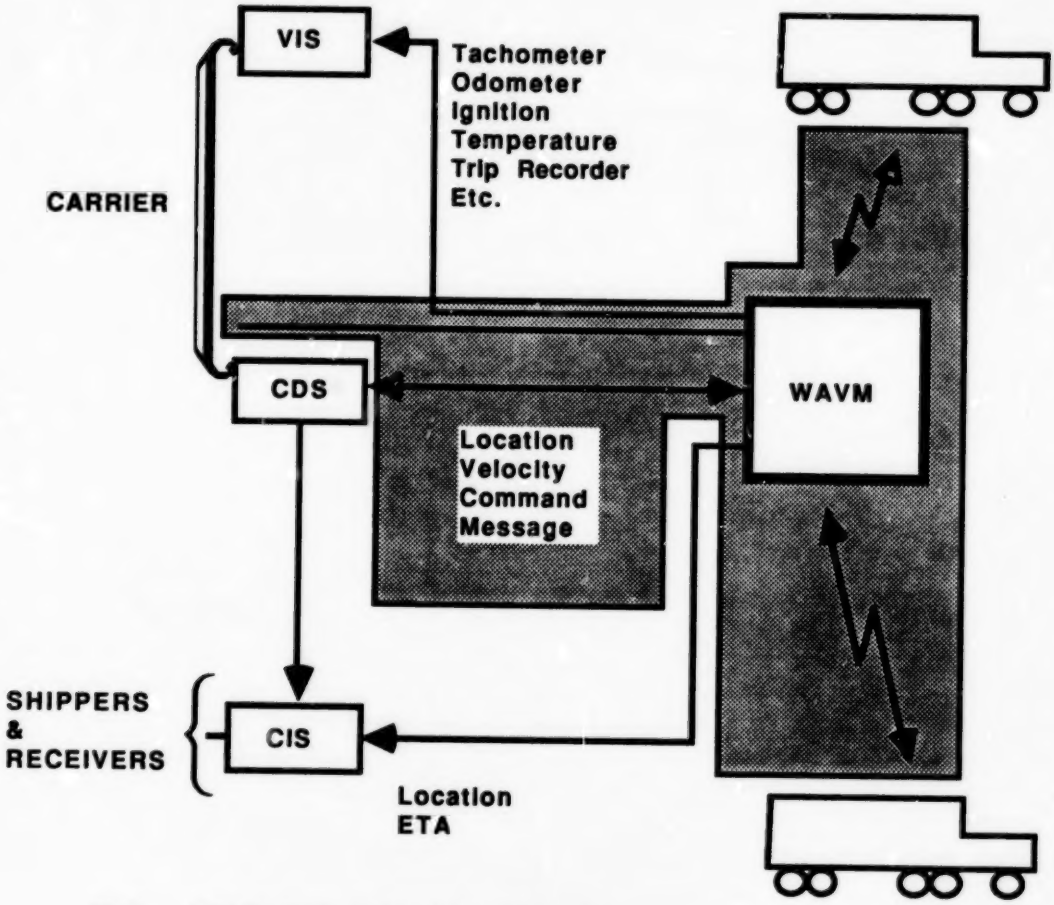


Figure 2/ WAVM System – An Important Missing Link



CDS – COMPUTER DISPATCH SYSTEM
CIS – CUSTOMER INFORMATION SYSTEM
VIS – VEHICLE INFORMATION SYSTEM

Figure 3/ Long-Haul Truck Route Diagram

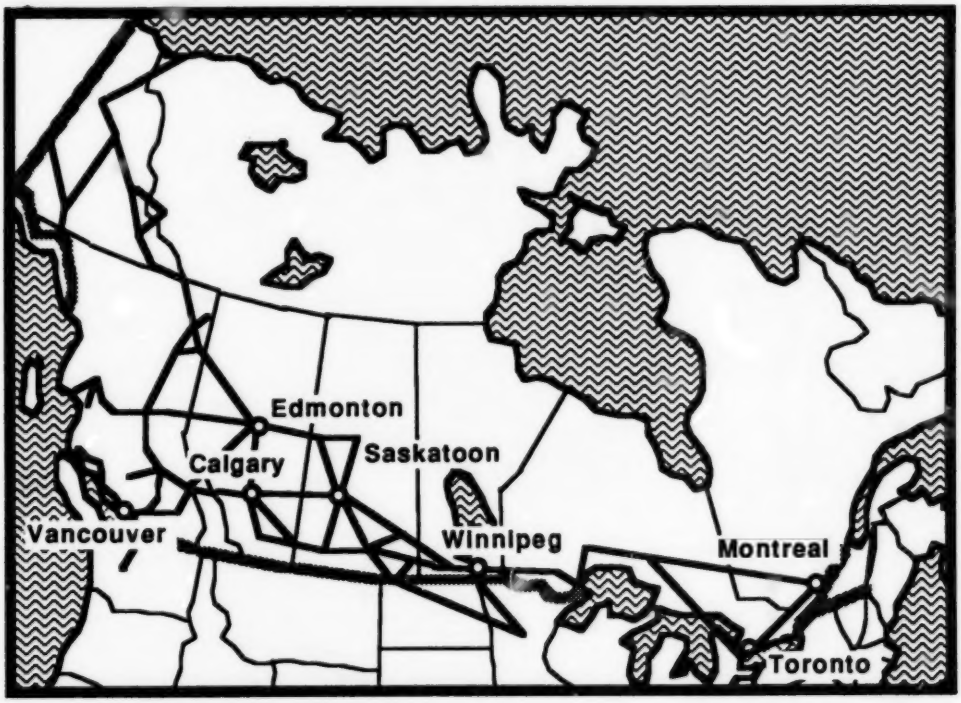


Figure 4/ Southern Ontario Truck Route Diagram

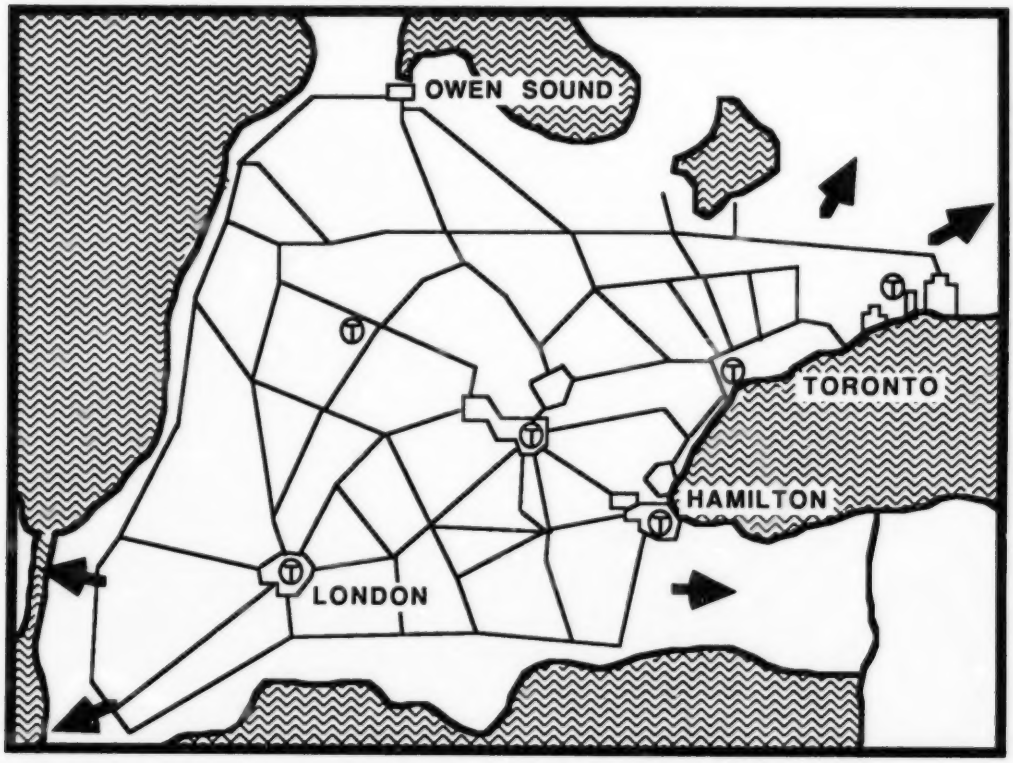


Figure 5/ Truck Fleet Dispatch System

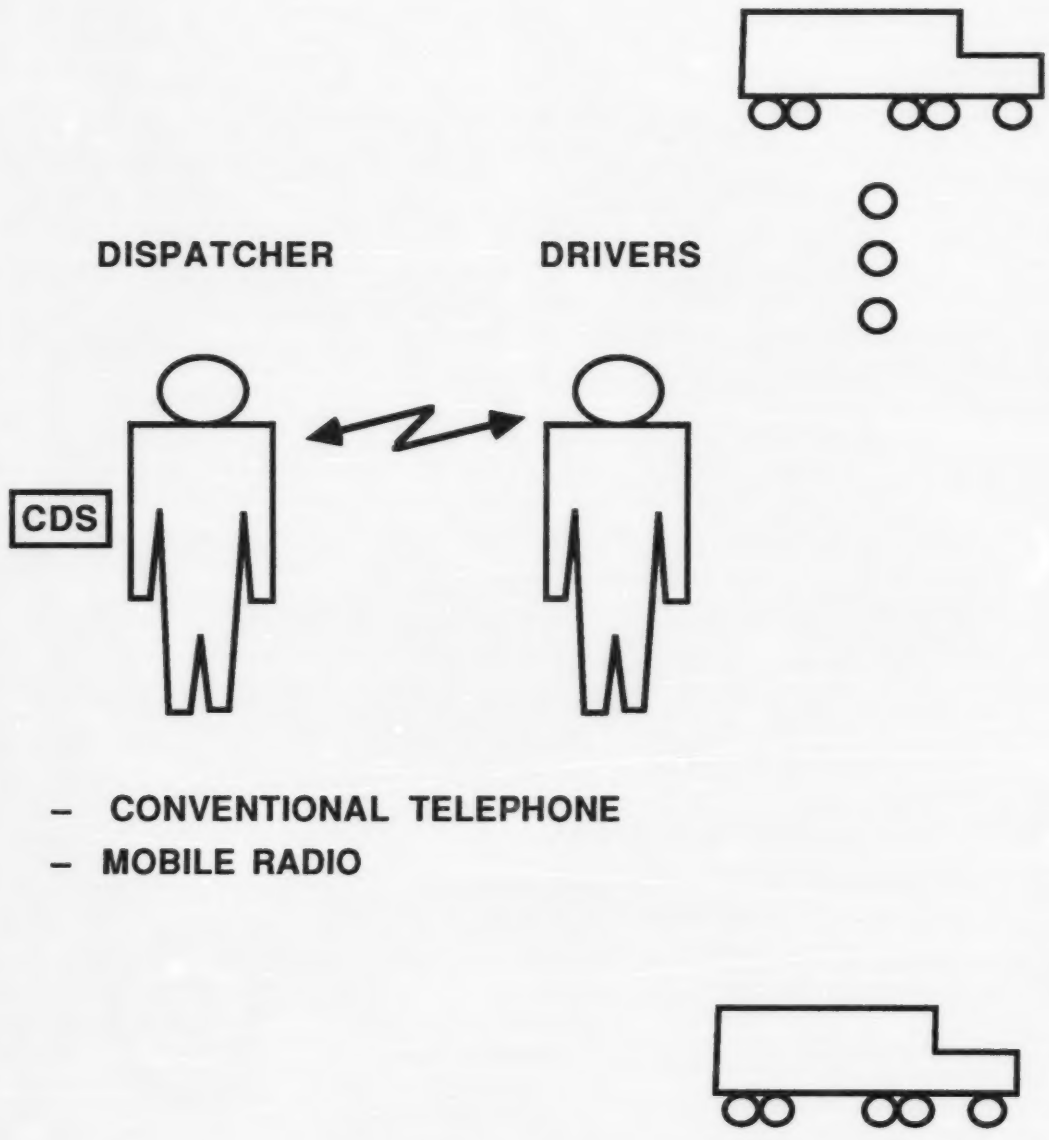
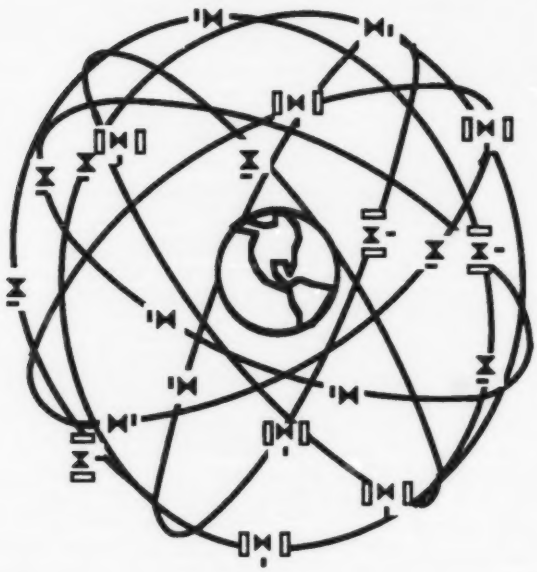


Figure 6/ Global Positioning System (GPS) Satellite Constellation



- **World-wide, all weather, continuous navigation**
- **Vehicle position, velocity, time**
- **Two-dimensional coverage**
- **Three-dimensional coverage**
- **Present time**
  – six GPS satellites in orbit
- **Operational constellation**
  – 18 satellites for 24-hour coverage

Figure 7/ MSAT System Concept

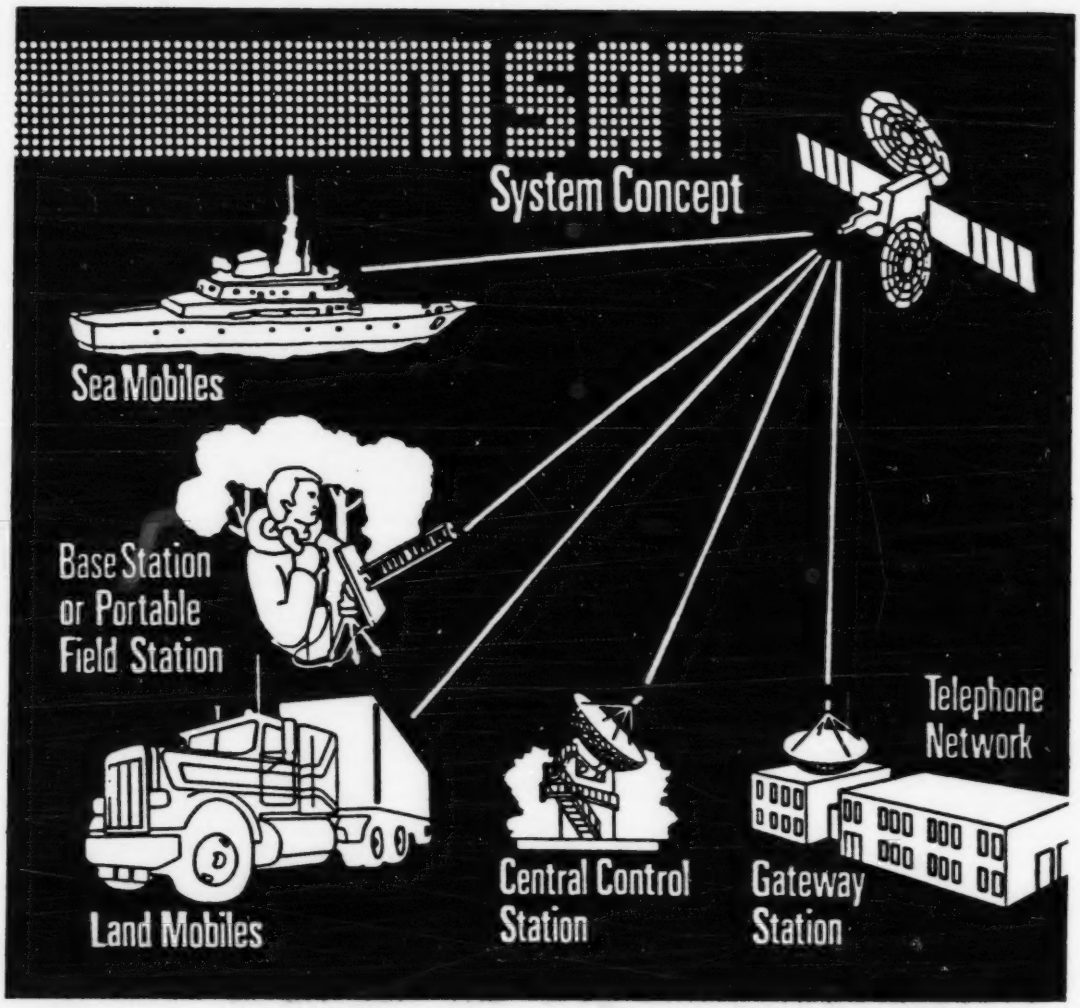
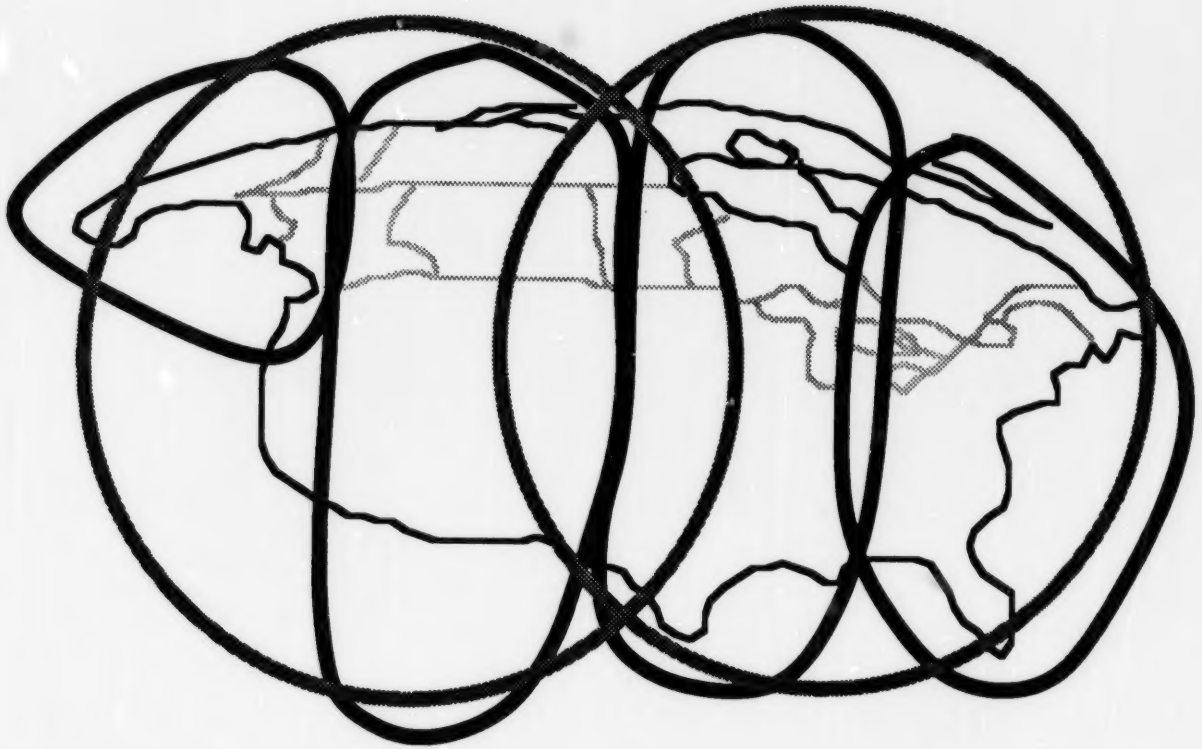


Figure 8/ MSAT Antenna Coverage



LEGEND: UHF
L-BAND

Figure 9/ Cellular Radio Concept

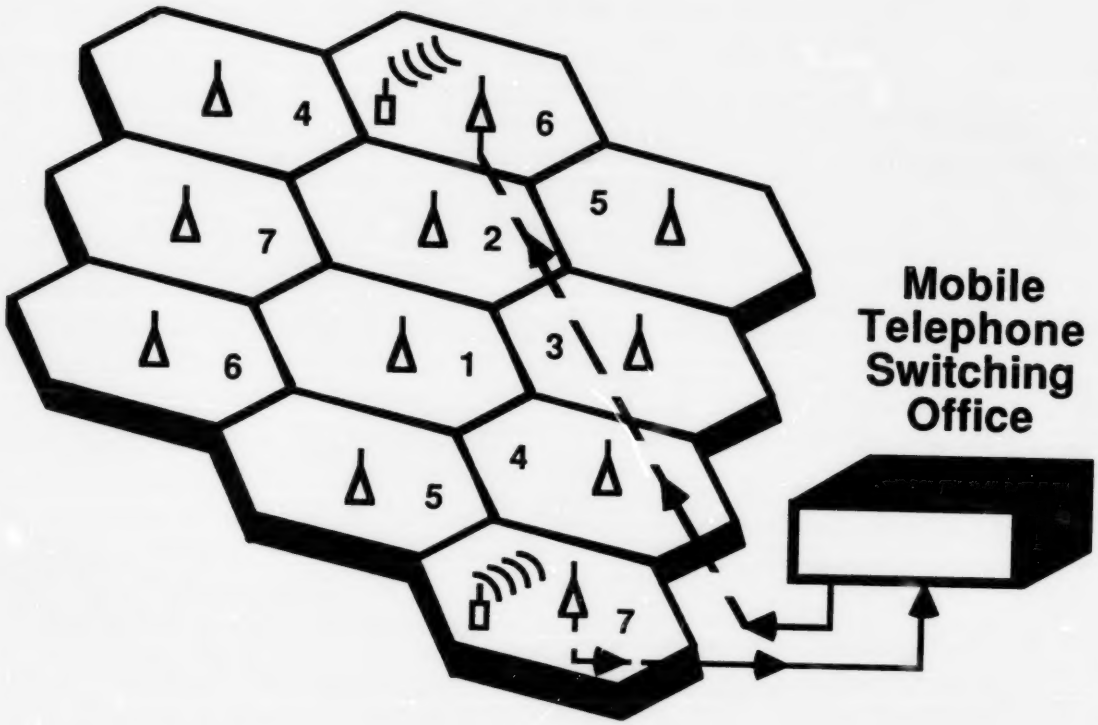


Figure 10/ Cellular Radio Coverage in Southern Ontario

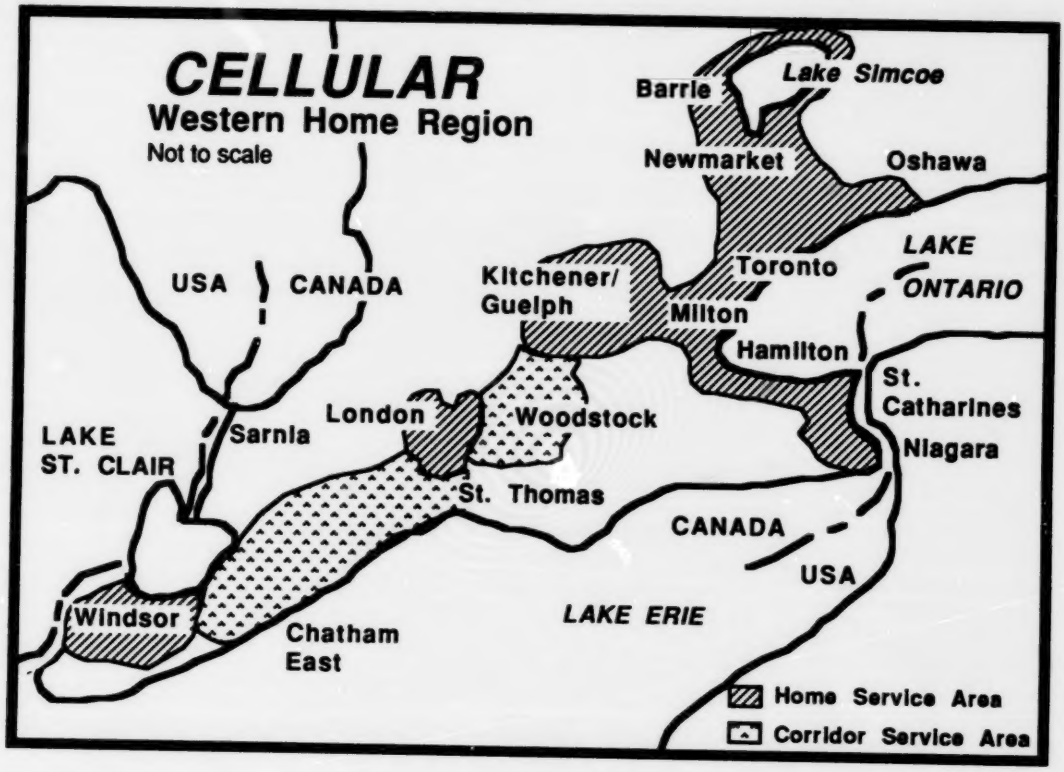


Figure 11/ WAVM System Functional Diagram

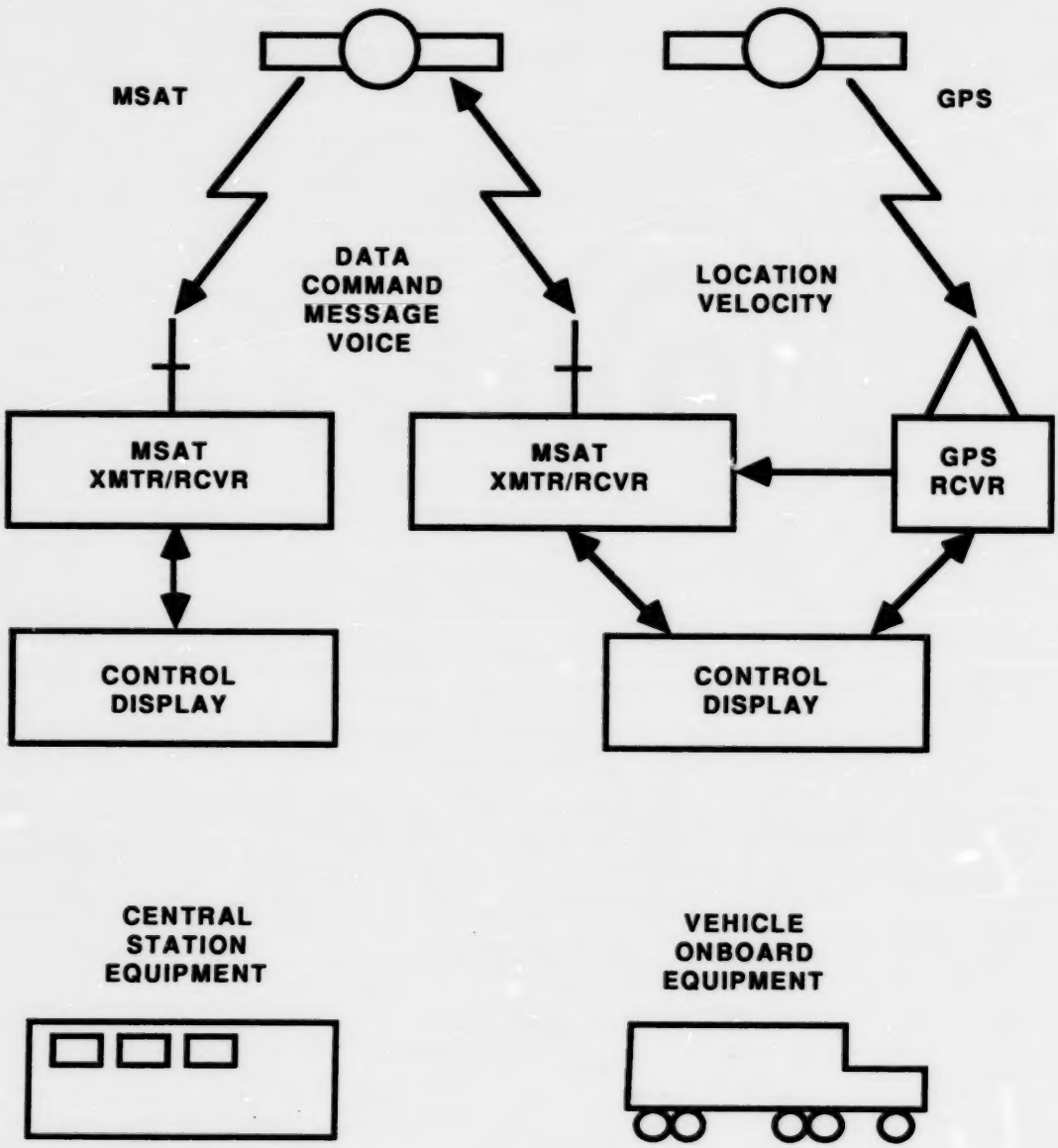


Figure 12/ Revenue Distribution of For-Hire Carriers Surveyed

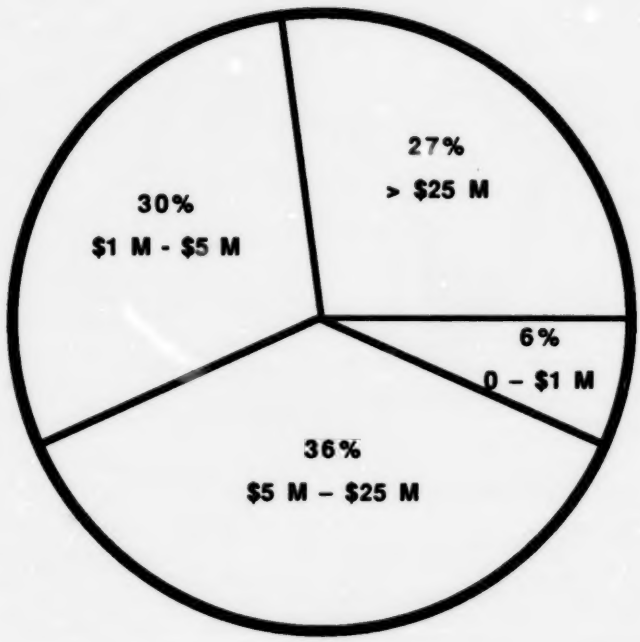
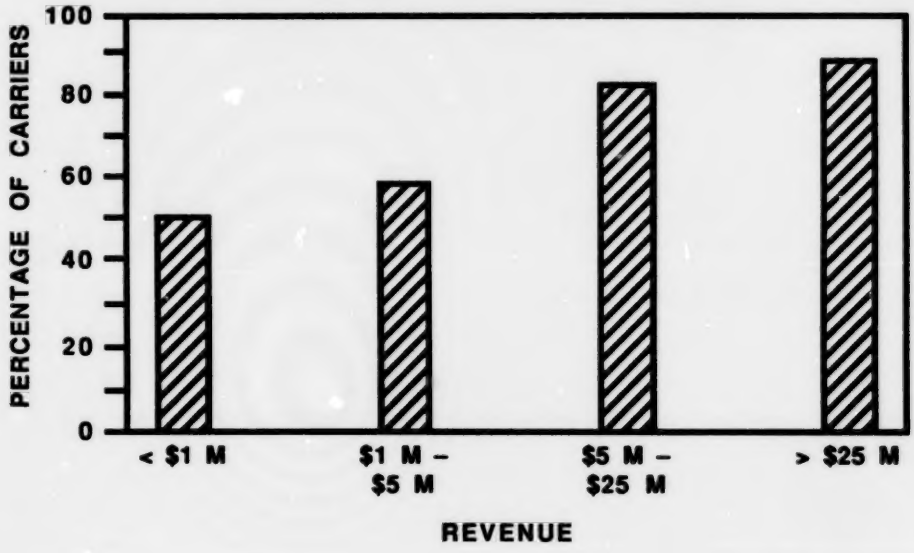


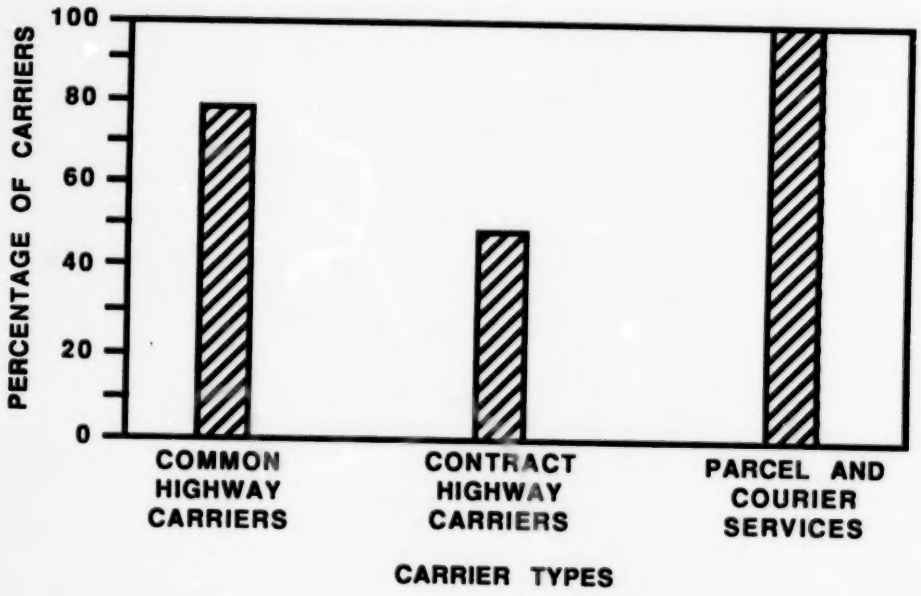
Figure 13/ Business Distribution of For-Hire Carriers Surveyed

Figure 14/ Percentage of For-Hire Carriers Interested in WAVM System – Based on Revenue



$$\% = 100 \times \frac{\text{"YES" TO WAVM RESPONSES WITHIN THE REVENUE CATEGORY}}{\text{TOTAL RESPONSES WITHIN THE REVENUE CATEGORY}}$$

Figure 15/ Percentage of For-Hire Carriers Interested in WAVM System – Based on Carrier Types



$$\% = 100 \times \frac{\text{"YES" TO WAVM RESPONSES WITHIN THE CARRIER TYPE}}{\text{TOTAL RESPONSES WITHIN THE CARRIER TYPE}}$$

Figure 16/ Expected WAVM System Applications By For-Hire Carriers

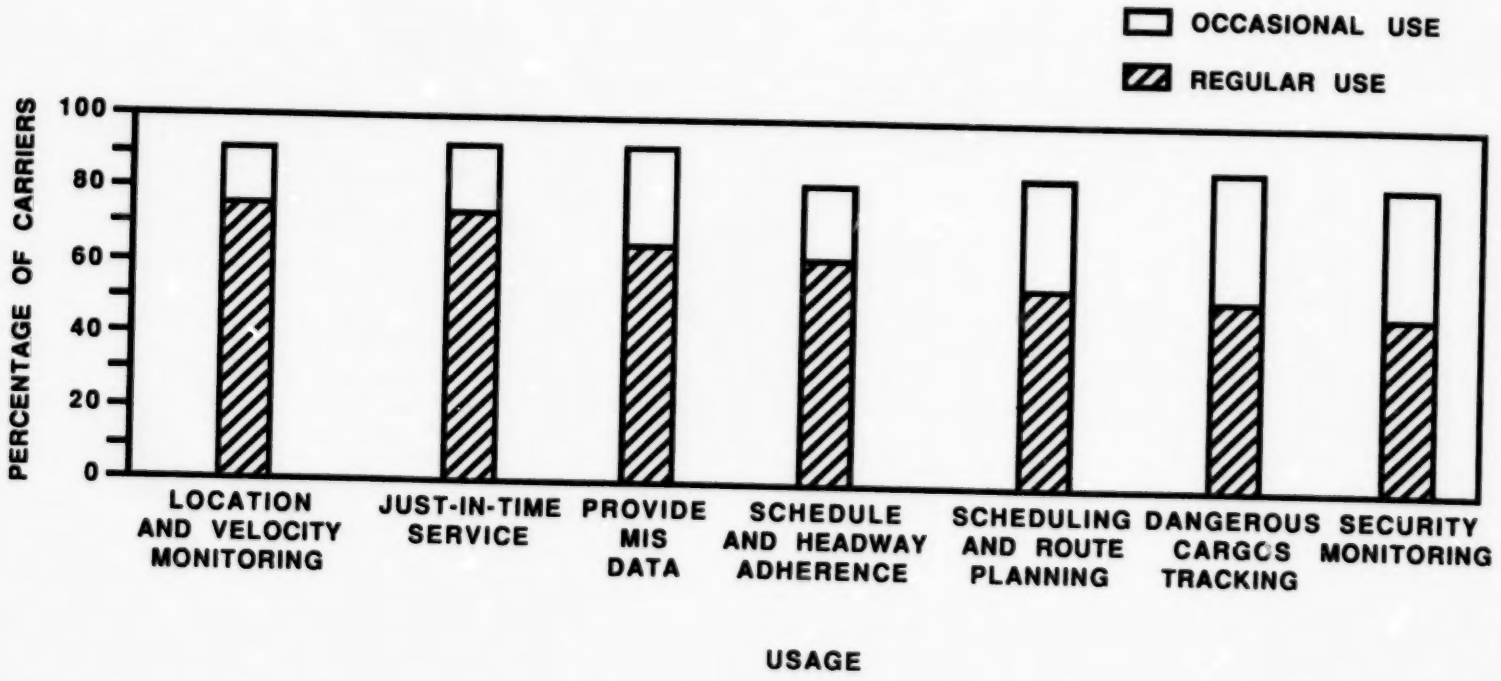


Figure 17/ Perceived Benefits of WAVM System Applications By For-Hire Carriers

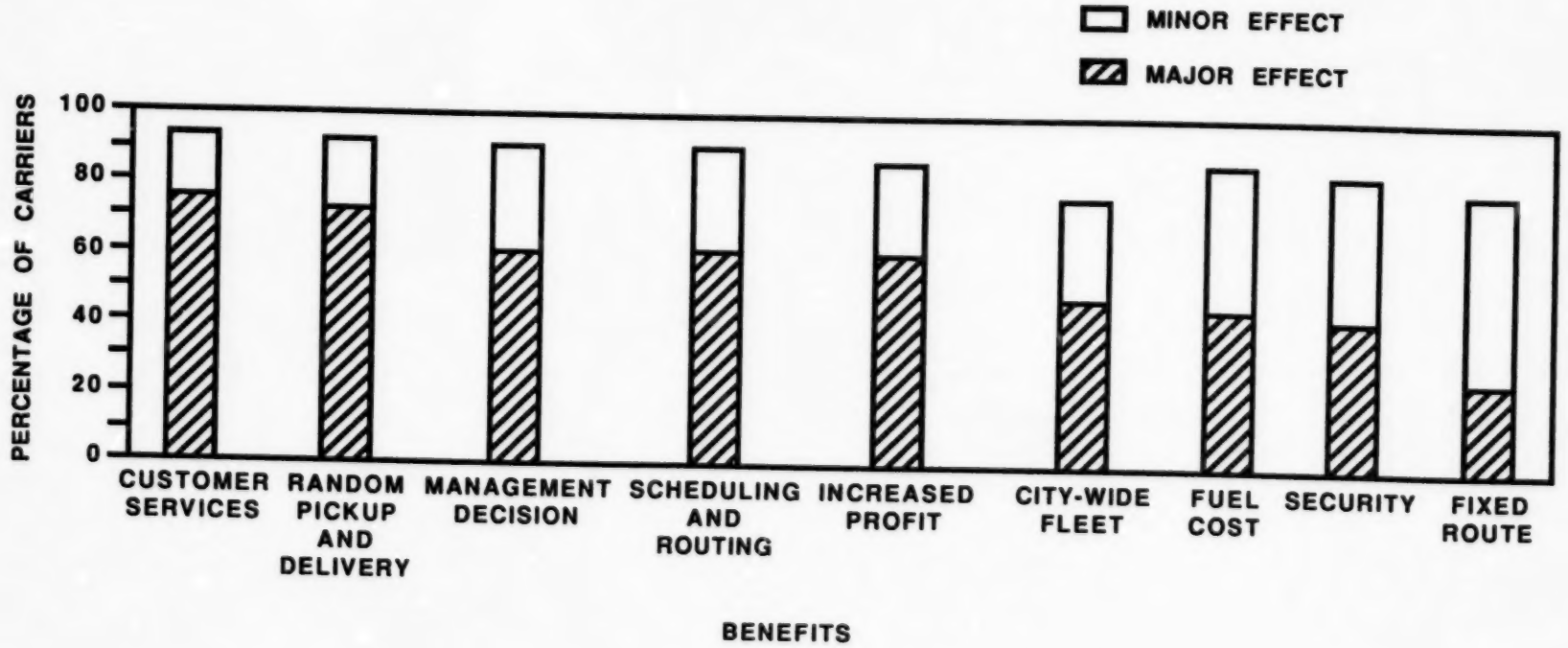


Figure 18/ Period of Information Exchange for Vehicle Location Monitoring

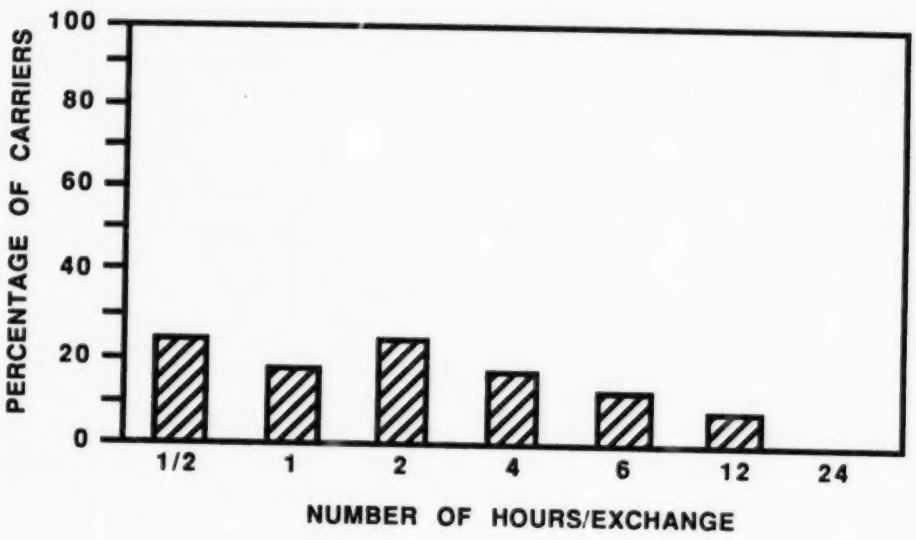


Figure 19/ Period of Information Exchange for Vehicle Schedule and Route Adjustment

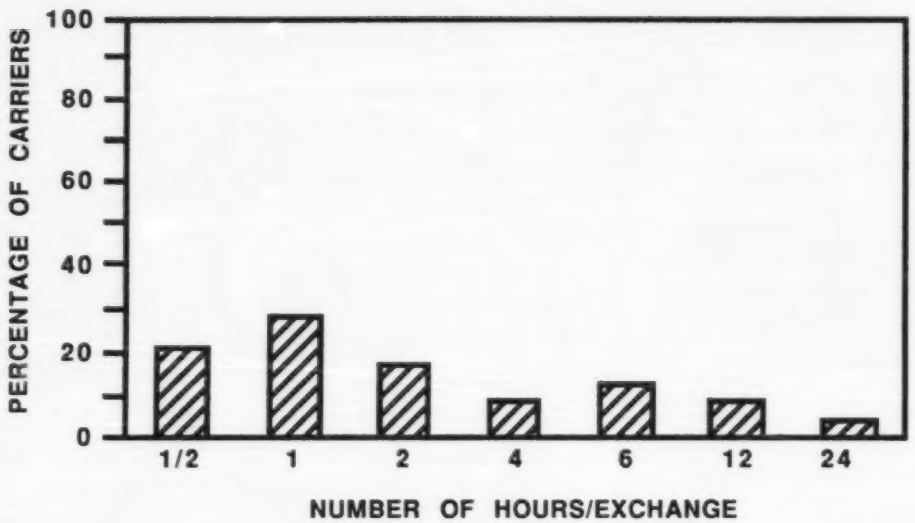
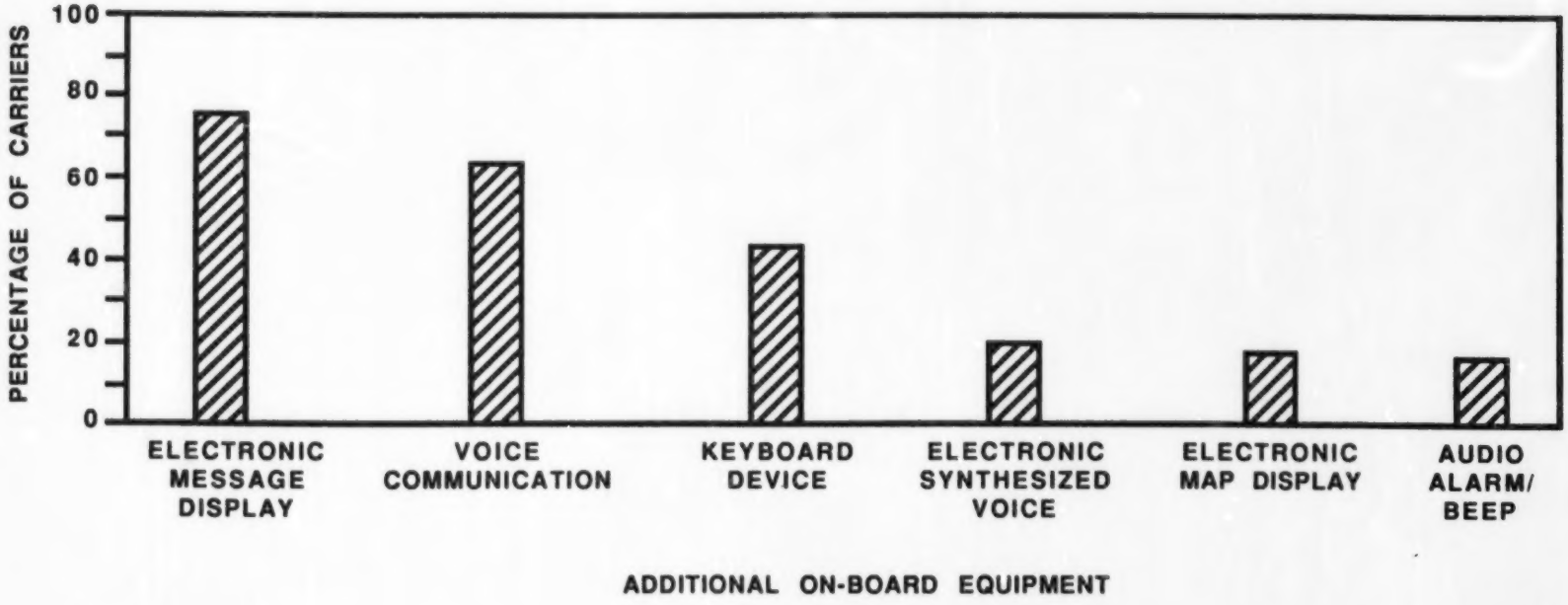


Figure 20/ Preference of Additional Vehicle On-board Equipment



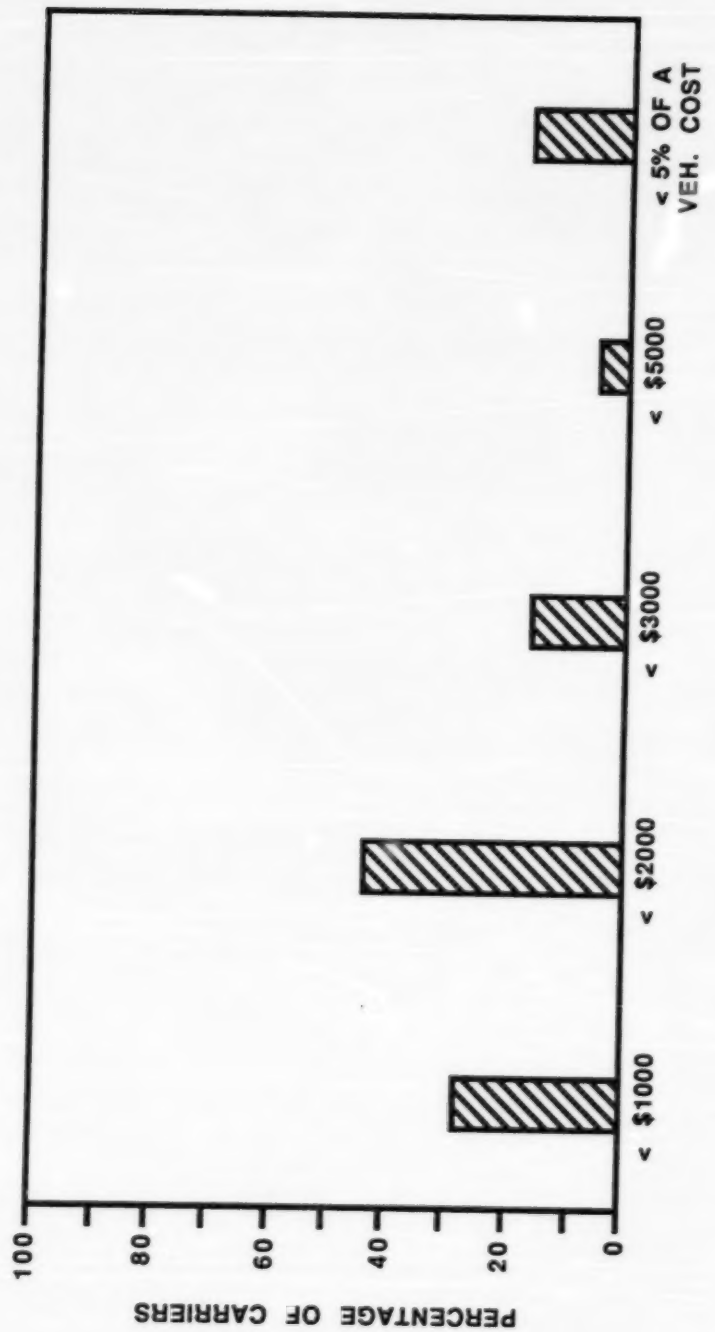


Figure 21/ Acceptable/Affordable Cost of WAVM Vehicle On-board Unit

Figure 22/ Acceptable/Affordable Cost of WAVM Central Control System

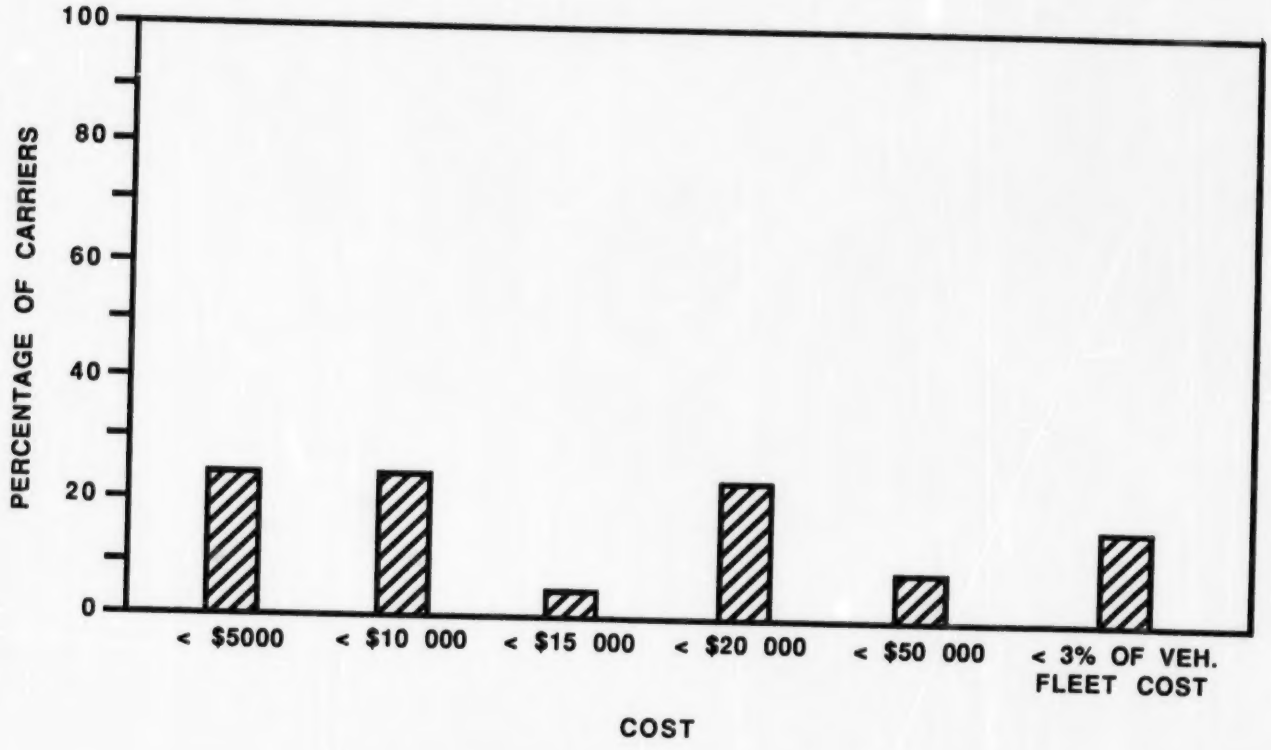


Figure 23/ Preferred WAVM System Implementation Strategy by For-Hire Carriers

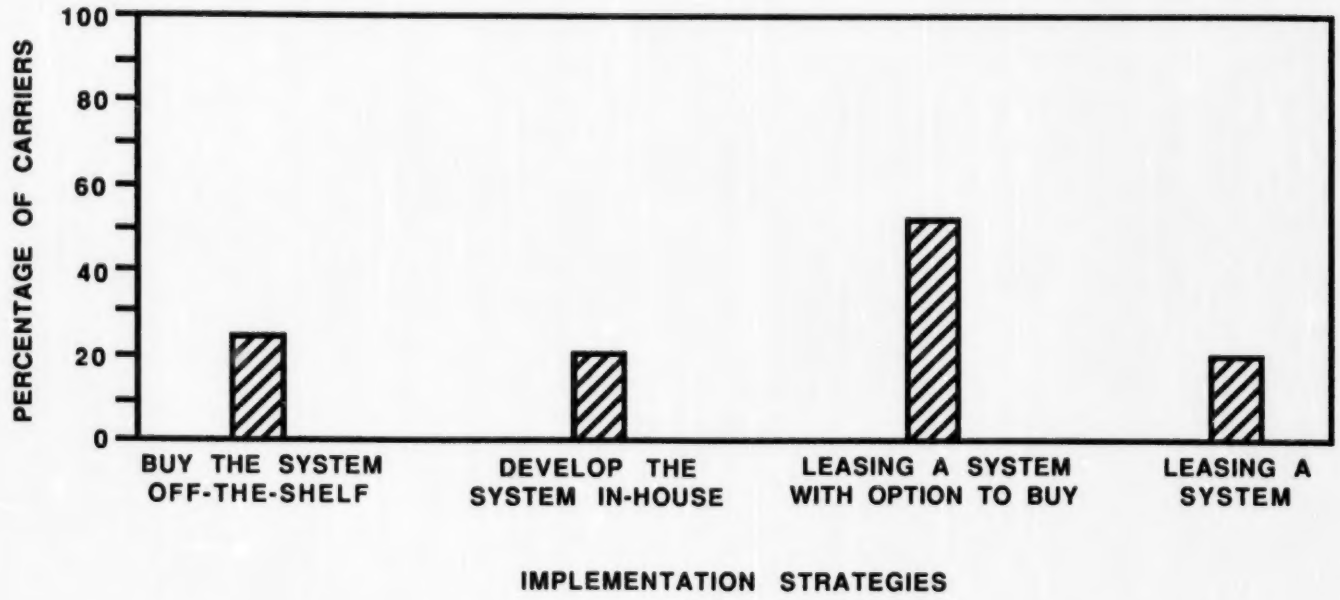


Figure 24/ Percentage of Vehicles to be Covered by WAVM System

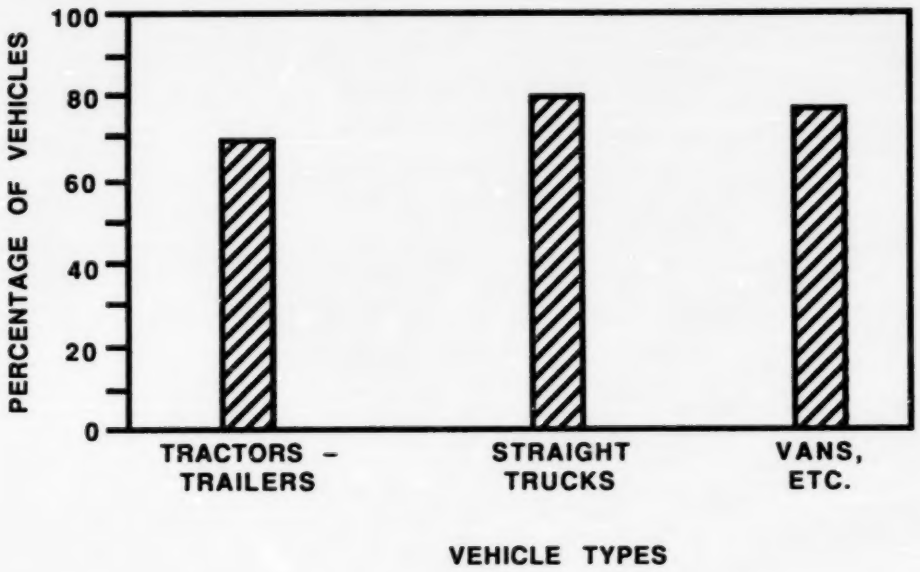


Figure 25/ Existing Satellite-Based WAVM Demonstration Configuration